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# The economics of visual disamenity reductions of offshore wind farms—Review and suggestions from an emerging field

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ABSTRACT

The offshore wind power generation market is currently experiencing large growth rates on a global scale and investments exceeding several billion euro are being made. From a welfare economic point of view there is a non-trivial economic trade-off between offshore wind generation costs and the visual impacts from offshore wind farms. Offshore wind farms close to the shore generate cheaper electricity, but also cause higher levels of visual impacts compared to locations at larger distances. In the present paper we carry out a review of the stated preference studies that have elicited the demand for visual disamenity reduction from offshore wind farms. The review has three objectives: (a) to present the results of the different surveys; (b) to explore the more technical parts of the different surveys; and (c) to present the frontiers in the assessment of the demand for visual disamenity reductions associated with offshore wind farm locations. The paper is based on the results from five different studies. The review indicates that locations of offshore wind farms which are close to the shore generate significant welfare losses and that these can be reduced by locating the wind farms at more distant locations. The results also show that the welfare economic costs vary in terms of a range of socio demographic characteristics, experience with wind turbines and recreational activities. Finally, the review suggests that the welfare impacts related to the spatial distribution of the wind farms, intergenerational effects and experience with wind turbines are potential areas that would be beneficial to explore in future studies.



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## 1. Introduction

Ten years ago the offshore wind power market was still in its development phase, though it was expected to play a significant role in global wind power development [1]. The construction and operation of the first large scale commercial wind farm at Horns Rev, Denmark, in 2003 marked a change in the offshore wind power industry. Today, several offshore wind farms are in operation and particularly in European waters, offshore wind farm development has accelerated significantly [2]. Although offshore wind turbines are in most cases more complicated and costly to develop and operate than onshore turbines [2,3], favourable wind regimes provide a strong motive for going offshore. In addition, visual impacts and impacts related to the noise of the turbines can be mitigated or even completely removed by developing offshore. When asked about their attitudes towards offshore wind farms, people mostly perceive offshore wind farms to be less intrusive than onshore ones, suggesting that locating wind farms offshore results in fewer external costs from a preference perspective [4–6].

This suggest that the visual impacts from the offshore wind farms in experiments and real life can be reduced by locating the wind farms at larger distances from the shore. Unfortunately, while locating offshore wind farms at large distances from the shore reduces the external cost of offshore wind power generation, it will in most cases increase the direct generation costs—often substantially.

A report by the European Environment Agency [7] showed that the investment costs, such as foundation, installation and grid costs of offshore wind farms increase linearly as distance from the shore increases and exponentially as water depths increase. As further distances from the shore are often associated with increased water depths, costs can increase substantially as an attempt is made to locate wind farms further offshore. For example, holding distance from the shore constant, an increase in water depth from 10–20 m to 30–40 m, increases investment costs by around 25%. The welfare economic benefits of visual disamenity reductions are thus far from being costless, and it is imperative to take into account the trade-offs associated with location choices when planning to make a multi-billion dollar investment in offshore wind farms. Given that the expected lifetime of offshore wind farms is at least 20 years, the choice of location can also have an impact in the more distant future and thus it is even more important to make the right choice of location.

This type of decision requires that both the generation costs and the external costs associated with different locations are estimated, and the costs and benefits of locating wind farms at different distances be compared, in order to determine an optimal set of wind farm locations. A number of studies have been dedicated to estimating the investment and generation costs associated with offshore wind energy [7–10]. Only a few studies, however, have assessed the external cost associated with the visual disamenities of offshore wind farms located at different distances from the shore. This paper aims to give a thorough and constructive review of these papers. The review will have several aims. First, the aim is to present the results of the different surveys, both in general terms, but also with an emphasis on how preferences vary in the sampled populations. Both systematic and unsystematic sources of heterogeneity in preferences can entail important information if specific groups or a large part of the population have distinctively different preferences. These potentially divergent preferences can have spatial and even dynamic effects on the external costs of the visual impacts. Acknowledging that the preferences estimated are contingent on both how the survey has been carried out, as well as the constructed hypothetical market, the review will also present the more technical parts of the different surveys, such as the number and types of elements/attributes in the hypothetical scenarios, spatial uncertainty and the type of demand model. By elaborating on the technical aspects of the studies, we hope to not only set the appropriate frame of the review in relation to the results, but also to give inspiration and guidance to future studies. Finally, the review aims to point out where the frontiers are in the assessment of the demand for visual disamenity reductions associated with offshore wind farm locations.

## 2. Review of the preferences for reducing the visual disamenities from offshore wind farms

Visual impacts from offshore wind farms are, as mentioned, an external cost of wind power generation. Accordingly, the assessment of the magnitude and variation of preferences related to the placement of offshore wind farms is essential for identifying an optimal set of locations. In a welfare economic context, the elicited demand for a reduction in the external cost should be based on the preferences of the appropriate population. In the economic valuation literature, preferences are elicited by two main methods; revealed- and stated preference methods. Revealed preference analysis of external costs has the advantage that the externality is a market good itself or that the level/size of the externality has an influence on the demand for a market good [11,12]. In many cases revealed preference data is not available because the externality at hand does not influence the demand for a market good, or the data is difficult or impossible to collect. To the authors' knowledge, no published revealed preferences exist which analyse the relation between the demand for a market good such as private properties and the location of offshore wind farms. The relation between house prices and the vicinity of onshore wind turbines has been assessed in a couple of papers and with mixed results. Some authors, notably [13,14] find a significant negative impact on house prices, whereas [15–18] do not find an effect.

The other type of economic valuation method is stated preference analysis. Two examples of the above are the contingent valuation method (CVM) [12,19–23] and choice experiments (CE) [24–27], which are based on the stated (hypothetical) demand for the externality. In CVM the aggregate value of a change in the supply or quality of a non-market good is estimated holistically by presenting the individual with a precise scenario description of the hypothetical good and the relevant change in the supply. Based on information regarding the rules of provision, present and future access to the good, as well as methods of payment, the individual is asked to state their valuation of the good. CE on the other hand builds on the theory proposed by Lancaster [28], where it is not goods per se, but rather the bundle of characteristics that they consist of that give utility to the consumer. Consequently, the demand for a good is derived from the demand for the characteristics that the good consists of [28,29]. CE is based on the recognition that any good or service can be described in terms of its attributes and aims to identify

the utility that individuals receive from the attributes which constitute the good or service in question [24]. This is accomplished by presenting respondents with a set of alternatives, typically one to three hypothetical alternatives as well as an alternative representing the status quo situation, also known as the opt-out- or reference-alternative. The alternatives define the good or service in terms of their key attributes, and different alternatives are described by varying levels of the attributes. By examining the trade-offs between attributes and attribute levels that are implicit in the choices made by respondents, it is possible to derive an estimate of the utility associated with the different attributes. If one of the attributes is measured in monetary units (i.e., costs), it is possible to derive estimates of respondents' WTP for the other attributes from the marginal rate of substitution between the monetary attribute and the other attributes [30].

Stated preference methods have been used to assess the external cost of different types of energy generation facilities like onshore wind turbines [23,27,31–33]. While CVM has been used to elicit the demand for mitigating the external effects from onshore turbines, the method has not been used to assess the demand for different levels of visual disamenity reduction resulting from offshore wind farms. Accordingly, this review will pay specific attention to papers which have used CE to elicit a monetary value for the visual impacts associated with the construction of offshore wind farms visible from the shore. In the next section, the setup and application of each study will be summarised, after which the findings from these studies will be jointly discussed and compared.

### 2.1. Ladenburg and Dubgaard [34,35]

This study was the first to address preferences for visual disamenity reduction of offshore wind farms and was based on a national survey in which the respondents in the sample were randomly drawn from the Danish Civil Registration System. In the initial sample, 700 respondents were invited to participate in the survey. The effective sample was 375 respondents, equal to a response rate of 53.6%. To estimate the demand for visual disamenities reductions, a "distance to the shore" attribute was included in the CE. The attribute could take four levels: 8 km, 12 km, 18 km and 50 km from the coast. Using visualizations of 5 MW turbines (100 m nacelle and 60 m blades = 160 m in total), a wind farm at 50 km would not be visible from the coast. The other attributes in the CE were "wind farm size" and "total number of wind farms to be erected". To facilitate the payment for reducing the visual impacts an annual fixed increase in the household electricity bill was used with the following cost levels: 0, 12.5, 23, 40. 80 and 175 €/household/year with the valuation scenario stipulated an increase of 3600 MW in energy produced by offshore wind farms.

The locations of the wind farms were not site specific. In the CE, each respondent evaluated three choice sets consisting of two hypothetical wind farm layouts (varying by the costs, the distance from the shore as well as the number of turbines per wind farm). The respondents were not given an opt-out alternative.

### 2.2. Ladenburg et al. [36]

The initial aim of the study was to test the effect of the so called Cheap Talk (CT) [37,38] to reduce hypothetical bias in stated preference studies, using CE as a specific case [39]. The case at hand was, however, the demand for visual disamenity reductions associated with the placement of offshore wind farms. The respondents were randomly sampled from a nationwide internet panel consisting of approximately 17,000 people. Initially, the desired sample size was set to $2 \times 350$ respondents (350 respondents would not get a CT script and 350 respondents who would get a CT script). To obtain these sample sizes 1242 respondents were e-mailed an invitation to participate in the survey. The effective sample size was 705 respondents, which is equal to a response rate of 56.8%. The aim of the survey (besides testing the effect of the CT) was to estimate the visual impact from offshore wind farms. To exclude potential wind power demand effects, the status quo alternative defined a situation in which the offshore wind farms were located at 8 km with no extra costs to the household. This ensured that the estimated demand for visual disamenity reductions was not confounded with a general preference for wind energy, as in the case when the choice is given between a wind turbine alternative relative to a non-wind turbine alternative. In the hypothetical alternatives, the offshore wind farms could be located at 12 km, 18 km and 50 km, representing reductions in the visual impacts compared to the 8 km status quo. At 50 km, the wind farm with 5 MW turbines (100 m nacelle and 60 m blades = 160 m total) would not be visible from the coast. As a payment vehicle, an annual fixed increase in the household electricity bill was used. The annual increase could take the values 100, 400, 700 and 1400 Danish Kroner (DKK) per household per year[1] . Visualizations for each of the wind farm scenarios were included in each choice set and respondents were also provided with a map showing the location of existing offshore wind farms and the expected location of the future offshore wind farms. Respondents each faced a total of six choice sets. The wind farm scenario stipulated the development of 7 wind farms with 100, 5 MW turbines in each wind farm. In total, this would give a capacity of 3500 MW (close to the 3600 MW governmental target).

### 2.3. Krueger et al. [40]

Krueger et al. [40] also use CE to estimate the demand for reduction in the visual disamenities from offshore wind farms. The study is based on a stratified random sample of households in the state of Delaware, USA. The three strata consisted of households living close to the Atlantic Ocean (Ocean sample), close to the Delaware Bay (Bay sample) and the other households in the state (Inland sample). The initial samples consisted of 400, 400 and 1200 households, respectively. The effective samples were 182, 203 and 564, respectively—giving an average response rate of 52% after accounting for bad addresses and for deceased and otherwise incapacitated respondents. In the survey each respondent faced three choice sets. Each choice set consisted of an opt-out alternative and two offshore wind alternatives. The opt-out alternative was defined as an expansion of the existing coal and natural gas generated power production and no offshore wind farms. The two offshore wind farm alternatives stipulated the development of a 500 turbine wind farm in which each turbine was approximately 135 m high (80 m nacelle and 55 m blades), which is slightly smaller than the 160 m high turbines used in the Ladenburg and Dubgaard [34,35] and Ladenburg et al. [36] studies. The location of the wind farms was site specific. More precisely, the exact beach location of the wind farm was an attribute in the CE. The wind farm could be located off the shore of Delaware Beach, Rehoboth Beach or Fenwick Beach. To estimate the demand for visual disamenity reductions a distance attribute was also included. In total, 5 distances were applied[2]: 1.44 km, 5.76 km, 9.60 km, 14.4 km and too far out to see. Visualisations of the wind farms at the different distances were included in the survey. Beside the cost attribute with payment levels of \$0, \$1, \$5, \$10, \$20 and \$30. (renewable energy fee on the households' monthly electricity bill for three years) two attributes related to the amount given to royalty funds, and the type of royalty fund contributed to. Three levels of payment (\$1 million, \$2 million

[1] This is equal to 13.4, 53.7, 94 and 187.1 €/household/year.

[2] The original distances are defined in miles: 0.9 miles, 3.6 miles, 6 miles and 9 miles.

and $8 million) and three fund types (beach nourishment, green energy and a general fund) were included.

### 2.4. Landry et al. [41]

The study applies a recreation demand model to estimate the economic impacts of having offshore wind farms in the waters of recreational beaches. The first part of the study focuses on the past and future travel patterns associated with specific beaches. Though the influence of wind farms is addressed, the reduction in the visual impacts is not directly examined. This is, however, done in the second part of the survey. Applying a CE, the demand for visual impact reductions from offshore wind farms is elicited. From an initial sample of respondents living in four coastal counties and twelve counties located adjacent to the coast, 118 households participated in the survey, which is equal to approximately 10% of the original sample. In the CE, wind farm locations were labelled as being either in offshore waters (Atlantic Ocean) or in sound waters (between the mainland and the Outer Banks barrier islands on the North Carolina Coast, USA). In both cases, the offshore and in sound distances from the coast varied and could take three levels each: Unobstructed by wind turbine views (no wind farm), wind farms 1.6 km from shore and wind farms 6.4 km from shore[3]. In addition, beach congestion levels, onsite parking fees and travel distances were included as attributes of the beach alternatives. The beaches in the choice set were generic and thus not site specific. In each choice set, the respondents had to choose between three policy alternatives (hypothetical beaches) and an opt-out alternative (stay at home). The respondents evaluated six choice sets in total. The study uses visualizations of 3+ MW turbines (80 m nacelle and 50 m blades = 130 m total), but the scenario description does not stipulate a specific increase in the wind power capacity offshore, such as the number of turbines or the total capacity increase.

### 2.5. Westerberg et al. [42]

This study used CE to understand the potential impacts of offshore wind farm development on tourism by interviewing coastal tourists in the Languedoc Roussillion region of France, i.e., a recreation demand model. The sample consisted of respondents sampled on 9 different beaches along the coastlines of two locations: L'aude and L'herault. The respondents were personally interviewed by five interviewers and approximately 50% of tourists asked were willing to participate in the survey[4] . In total 370 respondents were interviewed, resulting in an effective sample of 339 respondents. Three distance attributes were applied in the choice questions: 5 km, 8 km and 12 km. The wind farm attribute stipulated a 30 turbine wind farm of 3.6 MW turbines (typically 80 m nacelle and 55.5 m blades = 133.5 m total), equal to a total capacity of 108 MW. The other attributes included were wind farm related recreation, sustainable tourism options, and the payment vehicle. The wind farm related tourism was defined as whether or not recreational activities, such as boating, scuba and skin diving, and potentially angling would be allowed within the wind farm area. The sustainable tourism attribute was defined on the basis of whether or not the municipality had adopted a coherent environmental policy which favoured the extension of bicycle lanes, public transport, solar and PV panels, energy and water savings devices, the use of local and organic produce etc. Finally the payment vehicle was defined as a change in the accommodation price. Both positive and negative changes in the price were used. More specifically, the following levels were used (€/per week): −200, −50, −20, −5, +5, +20, +50 and +200. Each respondent evaluated eight choice sets consisting of two hypothetical alternatives and an opt-out alternative, which was defined as the current vacation destination and conditions (i.e., no coherent environmental policy, offshore wind farm or associated recreational activities). Visualizations for each alternative were included.

## 3. Is wind farm visibility a disamenity?

Overall, the results of the above surveys suggest that offshore wind farms that can be seen from the coast generate visual disamenities, and accordingly reduce the welfare of people. The observed willingness to pay (WTP) is a direct measure of the extent of this visual externality. However, as presented later, preferences also exhibit large levels of heterogeneity in the samples. Ladenburg and Dubgaard [34,35], Ladenburg et al. [36] and Krueger et al. [40] find that wind farms located at larger distances from the shore are preferred to wind farms located nearer to the coast, ceteris paribus. Landry et al. [41] also find that locations further from the shore (both offshore and in the sound) are preferred to locations closer to the shore, but the results are not significant when evaluating locations in the sound. In that case, the respondents expressed indifference between having offshore wind farms at 1.6 km, 6.4 km or no wind farms at all when deciding on the nature of their beach visits. Offshore, however, a wind farm at 1.6 km from the coast significantly reduces the probability of choosing the respective beach for recreation. Beaches with wind farms at 6.4 km from the coast seem to be equally preferred to beaches with no offshore wind farms. Westerberg et al. [42] present a latent class model which also suggests that the respondents in the sample hold preferences for reducing the visual impacts from offshore wind farms. In the model all three estimated segments expressed negative preferences for an offshore wind farm located at 5 km from the coast. However, when stating their preferences for wind farms located at 8 km and 12 km from the coast, Segment 1 expressed positive preferences for a wind farm located at 8 km and 12 km, Segment 2 expressed negative preferences for a wind farm located at 8 km but positive preference for a wind farm a 12 km and Segment 3 expressed that both wind farms at 8 km, and 12 km influence the choice of vacation negatively. The segments are distinguished as follows. Segment 1 is characterized by predominantly French tourists, loyal to the Languedoc Roussillion region, whose holiday is motivated by visiting friends and family. While Segment 2 also consists of a higher share of loyal Languedoc Roussillion visitors, these visitors are mainly younger, Northern Europeans whose holiday is predominantly culturally motivated. Finally, Segment 3 consists of mainly retired, French tourists, whose vacation is especially motivated by landscape and nature appreciation.

It must be kept in mind, however, that compared to Ladenburg and Dubgaard [34,35]; Ladenburg et al. [36] and Krueger et al. [40], there is a distinct difference in the model setup in Landry et al. [41] and Westerberg et al. [42]. In Landry et al. [41] and Westerberg et al. [42], the preferences for visual impact reductions are measured relative to an option where no wind farms exist at all. If the respondent holds a preference for wind energy relative to the current energy source, the parameter estimates of the distance variables also entail a wind energy value element. In Ladenburg and Dubgaard [34,35], Ladenburg et al. [36] and Krueger et al. [40] the estimated distance parameters are estimated relative to another wind farm alternative, thus, in principle, being a function of the difference in the visual impacts relative to the reference distances only.

[3] The original distances are defined in miles: 1 mile and 4 miles.

[4] The survey was conducted onsite (on the beach) and thus potentially suffers from avidity bias (over-sampling of frequent visitors). The latent class model with three segments suggests that respondents with a high avidity (loyal Languedoc Roussillion visitors) have different preferences. However, the study does not account for avidity bias as suggested in Hindsley et al. [43].

## 4. Diminishing demand for visual impact reductions

An interesting and clear finding in Ladenburg and Dubgaard [34,35], Ladenburg et al. [36] and Krueger et al. [40] is the declining marginal benefits of moving offshore wind farms further away from the coast. All three studies find that the marginal benefits of locating an offshore wind farm an additional km further from the coast are larger at near shore locations compared to locations further offshore. These results are illustrated in Figs. 1 and 2. In both figures the marginal benefit of moving the wind farm an additional km from the coast are reported in intervals that are related to the distance attributes used in the CEs in the respective papers.

As the figures clearly indicate, the benefits of moving the wind farms an additional km offshore are markedly larger in distance intervals nearest to the shore. Although the marginal WTPs between the studies cannot be directly compared due to differences in the scope (number of turbines installed and their capacity) and the setup of the surveys, the annual marginal WTP per household in the outmost distance intervals are close to one euro/km/household/year or less. It is also noticeable that the marginal WTP is conditional on the sample of respondents. In Krueger et al. [40], the marginal WTP in the Inland sample is generally low in all distance categories, whereas the Ocean sample has a particularly high marginal WTP for reducing the visual disamenities at intermediate distances. In Ladenburg and Dubgaard [34,35], people who use the coastal area for recreational purposes and people who can see offshore wind farms from their permanent or summer residence also attach much larger marginal benefits to moving offshore wind farms an additional km from the coast at locations near the coast. In the Ladenburg and Dubgaard [34], Ladenburg et al. [36] and Krueger et al. [40] setup, a visual disamenity would be indicated by an increased WTP for electricity for alternatives in which the wind farms are further from shore. In the Westerberg et al. [42] paper, an increase in visual disamenity would be indicated if respondents would have to be offered a price discount to accept a certain view. As such, while an increase in WTP indicates an increase in visual disamenity in the above mentioned papers, an increase in visual disamenity would be indicated by an increase in the willingness to accept (WTA) in the Westerberg et al. [42] paper (or correspondingly a lower WTP extra for the house). In Fig. 3, we have estimated the marginal benefits from moving an offshore wind farm an additional km from the coast. Positive marginal benefits denote lower levels of compensation/higher levels of WTP, whereas negative marginal benefits denote higher levels of compensation/lower levels of WTP.

As seen in Fig. 3, the marginal benefits of moving an offshore wind farm an additional km from the coast are markedly different in Westerberg et al. [42] compared to the other three studies in Figs. 1 and 2. In Segment 3, which also has the highest WTA for having the holiday at a beach with wind farms at 5 km, 8 km and 12 km from the coast, we observe the same trend as in the other studies in that the marginal WTA/km seems to be highest in the 5–8 km distance interval compared to the 8–12 km interval. Similar results appear to be evident in Segment 1, except that the respondents on average have expressed negative benefits for moving an offshore wind farm beyond 8 km from the coast. Interestingly, in Segment 2, the marginal benefit of moving a wind farm an additional km from the coast appears to be increasing. Accordingly, the respondents in Segment 2 seem to put a larger weight on moving a wind farm an additional km offshore from 8 km compared to 5 km. The Landry et al. [41] study only evaluates the preferences for locating offshore wind farms at two distances for each of the offshore locations (offshore and in sound). Accordingly, it is not meaningful to compare marginal WTPs/km at different distance intervals.

The marginal benefits of locating an offshore wind farm an additional km from the coast are of particular interest, because as mentioned, the costs of offshore wind power generation increase as the distance from the shore and the depth of the water increase [7,8]. Focusing on the results from Ladenburg and Dubgaard [34], Ladenburg et al. [36] and Krueger et al. [40] the very small levels of marginal WTP/km at distance intervals far from shore suggest that the optimal location of wind farms[5] will most likely be at distances were the turbines will be visible from the coast. This might be particularly evident in areas where the marginal costs/km are high, such as in coastal waters with a steep ocean bed.

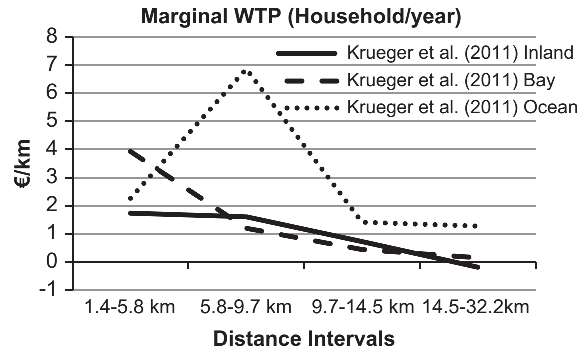



**Fig. 1.** Marginal benefits of moving an offshore wind farm an additional km from the coast, based on Krueger et al. [40].

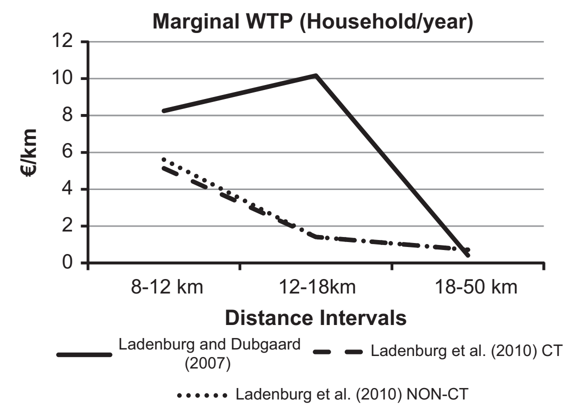



**Fig. 2.** Marginal benefits of moving an offshore wind farm an additional km from the coast, based on Ladenburg and Dubgaard [34] and Ladenburg et al. [36].

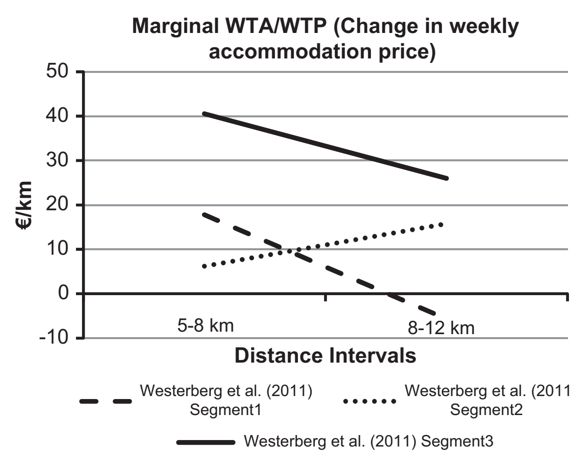



**Fig. 3.** Marginal benefits of moving an offshore wind farm an additional km from the coast, based on Westerberg et al. [42].

[5] The optimal distance is where the marginal cost of visual disamenity reductions is equal to the marginal benefits, all things being equal.

While the above mentioned reasoning is not supported by all the segments in Westerberg et al. [42], this discrepancy in results may be attributed to differences between the study and the aforementioned ones. As diminishing marginal benefits of reducing the visual impacts can have a large influence on the choice of location and the subsequent welfare calculations associated with wind power generation, these issue call for further research.

## 5. Heterogeneity in preferences

Most of the studies examined in this paper report that preferences are heterogeneous. In the sections below, we review the different types of heterogeneity unveiled in these papers. The review is structured as follows. Initially, we focus on the relation between standard demographics and preferences for visual disamenity reductions. This is followed by a presentation of how recreational activities and preferences are related. We then examine how experience with wind turbines can have an influence on preferences and the spatial distribution of preferences. Finally, we present the results related to unobserved heterogeneity in preferences.

### 5.1. Socio-demographic characteristics of the respondents

A number of the studies examined in this paper have found that preferences for reduced visual disamenities resulting from offshore wind farms vary with age. Ladenburg and Dubgaard [34] find that the younger part of the sample practically has no demand for reducing the visual disamenities from offshore wind farms. In Krueger et al. [40] a significant age effect is detected in the Inland sample but not in the Bay and Ocean samples. In the Inland sample, older respondents have stronger preferences for the coal/natural gas alternative relative to the offshore wind farm alternatives. This suggests that offshore wind power is less favoured relative to coal and gas in the older population. Westerberg et al. [42] also find evidence that older respondents perceive the visual impacts to be more severe than younger respondents. Segment 3, which requires the largest level of compensation for having offshore wind turbines at 5 km, 8 km or 12 km from the shore, has a significantly larger share of older respondents. Respondents from Segments 1 and 2, on the other hand, have weaker preferences for moving turbines further offshore, or even see offshore wind farms as an amenity in the choice of vacation location. These two segments have a significantly lower number of older respondents. In summary, the studies suggest that younger people might be less negatively affected by the visual impacts resulting from offshore wind farms. The difference in acceptance of wind turbines between younger and older respondents is also found in the literature examining general attitudes towards wind energy [44–50], though some studies find mixed results [51,52].

The interesting question in this regard is whether the age effect is permanent (a generation effect) or whether the effect wears off as the respondents become older. If the age effect is permanent, the welfare economic benefits of locating wind farms at larger distance from the shore will be smaller in the future. More specifically, if the locations of the offshore wind farms are based on the preferences of the present generation, the level of visual disamenity reductions might be too high in the nearer future and thus no longer optimal. Consequently, it would be beneficial from a power generation point of view, to take this into account when placing future offshore wind farms. This possible persistence of the apparent age or generation effect calls for further research.

Other socio-demographic characteristics also seem to have an influence on preferences. Ladenburg and Dubgaard [34] find that respondents from middle and high income households have a significantly higher WTP for reducing the visual impacts of offshore wind farms. Krueger et al. [40] find some evidence that people with higher levels of educations have a lower WTP for siting offshore wind farms further offshore. In the Ocean sample, they also find that male respondents dislike the offshore wind farm alternative more than female respondents. If this is governed by the perception of the visual impacts, the results are in line with Ladenburg et al. [36]. While Ladenburg et al. [36] do not make a direct test of heterogeneity in preferences, they do estimate separate models for male and female respondents and find that female respondents have weaker preferences, and thus are not willing to pay as much as male respondents to reduce the visual impacts of offshore wind farms. Landry et al. [41] do not report specific heterogeneity in preferences with regard to the socio-economic characteristics of respondents.

### 5.2. Recreational variables

One of the strongest arguments against offshore wind power development is the expected negative impact on the economic activities associated with recreation demand in the coastal region. More specifically, it has been a general concern that the placement of offshore wind farms close to the coast will make people change their choice of recreational area to locations with no offshore wind farm in sight [48]. If this is the case, it could have significant consequences for local communities, municipalities and perhaps even larger regions, whose economies are directly or indirectly (through taxes) dependent on the coastal related recreational activities.

Both Ladenburg and Dubgaard [34,35] and Krueger et al. [40] frame the preference elicitation mechanism as a choice of electricity generation and not a direct choice of which beach to visit. Accordingly, a direct assessment of the visual impacts in terms of loss in visitor days and the associated revenue lost cannot be made. However, as both studies include recreational variables in their attempt to capture heterogeneity in preferences, a more indirect assessment can made. Ladenburg and Dubgaard [35] estimate the demand for visual disamenity reduction among boaters, anglers and people who generally visit the beach often. Controlling for income effects, they find that anglers and boaters have significantly higher levels of WTP for moving offshore wind farms to larger distances than respondents who do not have similar recreational habits. Indications of similarly strong preferences among frequent users of the beach are also found in the paper. As such, Ladenburg and Dubgaard [35] conclude that in areas with fewer recreational activities, the optimal location of offshore wind farms may be closer to the coast than in areas where a higher demand and supply of recreational activities is observed. It is worth noting, however, that Ladenburg and Dubgaard [35] did not specify locations of future wind farms. Accordingly, the recreationally dependent demand for visual disamenity reductions could be conditional on the choice of location. In Krueger et al. [40] one of the variables included in the analysis is the number of days spent at the beach. Interestingly, the preferences for locating an offshore wind farm along the coast (relative to an expansion of coal and gas) appear to be independent of the number of days the respondents have spent on the beach the previous year. In this respect, the results point in somewhat different directions.

The models used in Landry et al. [41] and Westerberg et al. [42] can be categorised as recreation demand models, and can thus directly estimate the effects of offshore wind farms on recreational patterns. As the presentation of the studies indicates,

the location of the wind farms can have an influence on the stated recreational behaviour of the respondents. Across all three latent segments in the samples, Westerberg et al. [42] find that an offshore wind farm located 5 km from the coast has a negative impact on the propensity to spend the vacation at the specific beach/city. Offshore wind farms located at larger distance have a mixed impact in the recreation behaviour in the three segments. Offshore, Landry et al. [41] also find evidence that the nearest wind farm location influences recreational demand significantly, whilst wind farms located further offshore do not. Wind farms in the sound do not influence the recreational demand.

### 5.3. Experience with wind farms

The economic literature has several examples of how knowledge and familiarity with the good at hand influences demand both positively and negatively. In a study eliciting the preferences for biomass based electricity in Arkansas, Florida and Virginia, respondents with higher levels of knowledge of other sources of natural resource based energies had a higher demand for biomass based electricity production, whilst controlling for income effects and the level of education [53]. In a demand study for Green Power Partners (GPP) produced appliances, Ward et al. [54] find that familiarity with GPP increased demand. In contrast Bollino [55] find that knowledge of renewable energy sources reduce demand significantly. Although offshore wind farm capacity is increasing, the number of people who have direct experience with – or specific knowledge of – offshore wind farms is expected to be limited. Given the above findings, we would expect demand for visual disamenity reductions to potentially change as more offshore wind farms are constructed and experience with offshore wind farms increases. This could influence the optimal location of offshore wind farms. The only study that accounts for experience with offshore wind farms is Ladenburg and Dubgaard [34]. When the study was launched, six offshore wind farms were in operation. Nearly 5% of the sample had a view of an offshore wind farm from either a permanent or summer residence. Interestingly, the results suggest that these respondents had significantly stronger preferences for moving the offshore wind farms further from the shore. More specifically, the demand was a factor of approximately four times higher, compared to respondents who did not have a view of an offshore wind farm from a permanent or summer residence.

Krueger et al. [40] find that experience with onshore wind turbines increases the demand for offshore development relative to an expansion of coal or natural gas. However, conditional on having an offshore wind farm along the coast, experience with onshore turbines does not seem to influence placement preferences in terms of distance of the wind farms from the shore.

The two studies indicate two directions that the effect of prior experience with wind turbines might have. The first suggests that experience with offshore wind farms (in terms of having them in the viewshed) seems to drive up the demand for visual disamenity reductions of future offshore wind farms. This suggests that people who have a wind turbine in the viewshed experience a higher welfare loss compared to respondents who do not have an offshore wind farm in the viewshed. This indicates that it might be optimal to locate wind farms in coastal residential areas at relatively large distances from the shore. Though not a preference study, a supportive unveiling of the importance of the visual impacts and experience is Ladenburg [51], who samples two groups of Danish respondents with distinctly different experiences of the visual impacts from offshore wind farms. In one sample (Nysted), the respondents live near an offshore wind farm located relatively close to the shore, whereas the respondents in the other sample (Horns Rev) live near an offshore wind farm which is located relatively far from shore. Comparing the perceptions of the visual impact from offshore wind farms between the respondents in the two samples shows that the level of visual impacts from existing offshore wind farms has a significant impact on the perception. The respondents in the Nysted sample perceived the visual impacts as being significantly more negative than the Horns Rev sample. Clearly more research is warranted in these matters.

The second effect, found in Krueger et al. [40], is the effect of prior experience with onshore wind turbines on the demand for offshore wind power. Although we cannot directly interpret the results as a preference for offshore wind farms relative to onshore turbines, the results suggest that demand for offshore wind energy relative to coal/gas generation might increase as more onshore wind turbines are erected. Interestingly, Ladenburg [56] finds similar results in a survey focusing on the attitudes towards existing offshore wind farms. Controlling for a large number of variables such as gender, age, education and income, the study finds that respondents who have onshore wind turbines in the viewshed are significantly more positive towards offshore wind farms than those respondents who do not.

### 5.4. Spatial economics

In recognition of geographic heterogeneity in preferences and the impact of location and configuration on decisions, the investigation of spatial dimensions of problems has intensified [57]. Accounting for spatial processes in the analysis of preference structures has been found to give a more complete understanding of how preferences are distributed in sampled populations [58–60]. With respect to wind power development, spatial relations have been demonstrated in Ladenburg and Möller [50], who find that the acceptance of offshore wind farms might be significantly less among populations living close to offshore wind farms. If the demand for visual impact reductions follows a similar pattern, this could have an important influence on the welfare impacts of locating wind farms at different distances. None of the reviewed studies have explicitly addressed the spatial properties of the demand for visual disamenity reduction from offshore wind farms. That being said, Krueger et al. [40] include a distance from the beach measure in their analysis. Furthermore, both Krueger et al. [40] and Westerberg et al. [42] have sampled spatially, which gives grounds for some spatial distribution insights.

In the Krueger et al. [41] paper, the distance that people live from the beach has a significant but also mixed influence on the choice of offshore wind farm expansion over that of the expansion of coal and gas. Overall, respondents from the Inland sample (who, on average, live furthest from the coast) clearly have the weakest preferences for reducing visual disamenities, when compared to the Ocean and Bay samples. Though the above is a discrete and rather rough type of spatial analysis, the results could indicate that the further people live from an area in which the offshore wind farms are located, the weaker preferences are for reducing visual impacts (a classic distance decay effect [61]). These results are somewhat supported by Westerberg et al. [42]. The respondents in Segment 2, which have a significantly higher number of respondents living in Northern Europe and thus living far from the coastline of interest in France, seem to hold relatively weaker preferences for visual impact reductions compared to the respondents in Segment 3. These differences are particularly evident in the case of choosing a vacation area with a wind farm at 12 km. In this case, the respondents in Segment 2 are *willing to pay* nearly 43 euro/week compared to the respondents in Segment 3, who requires a *compensation* of 39 euro/week. This could suggest that people living far from the area of attention have weaker preferences for reducing the visual disamenities in terms of the level of compensation required to stay for a week of vacation. However, the respondents in Segment 1 also have

**Table 1**
Unobserved heterogeneity in preferences and the estimated probability to have a negative preference for visual disamenity reductions.

| Study | Variable | Estimated mean | Estimated standard deviation | Prob. negative/neutral preferences for visual disamenity |
|---|---|---|---|---|
| Landry et al. [41][a] | Distance 1 mile $_{\text{Ocean View}}$ | −0.6693** | 0.9194** | 0.23 |
| | Distance 4 miles $_{\text{Ocean View}}$ | 0.1933[NS] | 1.2585** | 0.56 |
| | Distance 1 mile $_{\text{Sound View}}$ | −0.3473[NS] | 0.8211** | 0.34 |
| | Distance 4 miles $_{\text{Sound View}}$ | 0.0747[NS] | 0.7109† | 0.54 |
| Krueger et al.[40] | | | | |
| Inland | Distance 3.6 miles | 1.05*** | 1.66* | 0.26 |
| | Distance 6 miles | 1.90*** | 2.19** | 0.19 |
| | Distance 9 miles | 2.39*** | 1.49* | 0.05 |
| | Distance to far to see | 1.93*** | 0.01[NS] | *0.00*[b] |
| Bay | Distance 3.6 miles | 2.58** | 0.26[NS] | *0.00* |
| | Distance 6 miles | 3.28* | 5.26[NS] | *0.27* |
| | Distance 9 miles | 3.60** | 1.26[NS] | *0.00* |
| | Distance to far to see | 4.00** | 5.41* | 0.23 |
| Ocean | Distance 3.6 miles | 0.62[NS] | 10.35[NS] | *0.48* |
| | Distance 6 miles | 2.29*** | 0.33[NS] | *0.00* |
| | Distance 9 miles | 2.72*** | 0.81[NS] | *0.00* |
| | Distance to far to see | 4.14*** | 1.99[NS] | *0.02* |
| Ladenburg and Dubgaard [34][c] | | | | |
| | Distance 12 km | 0.913*** | 0.001[NS] | *0.00* |
| | Distance 18 km | 1.913*** | 0.717[NS] | *0.00* |
| | Distance 50 km | 2.502*** | 2-431*** | 0.15 |
| Ladenburg et al. [36][d] | | | | |
| Non cheap talk | Distance 18 km | 0.4601** | 1.9612*** | 0.41 |
| | Distance 50 km | 0.7786*** | 1.0759*** | 0.23 |
| Cheap talk | Distance 18 km | 0.1913[NS] | 1.7531*** | 0.46 |
| | Distance 50 km | 0.7051*** | 0.7009* | 0.16 |
| | Correlation 18 km:50 km | 0.5751** | 0.26624[NS] | |

*Notes*: NS indicates no significance, † significance at 90% level, * significance at 95% level, ** at 99% level and *** at 99.9% level.

[a] The estimates are based on the Weighted Data in table 6 in the paper.

[b] The estimated probabilities in italic are based on an insignificant estimate of the standard deviation.

[c] We have run an RPL model on the data from Ladenburg and Dubgaard [34] assuming that the unobserved heterogeneity is normally distributed and while controlling for heterogeneity in preferences in relation to the significant variables (age, viewshed and income) in Model 3 in the original paper.

[d] The reference category is a wind farm at 12 km.

weaker preferences compared to Segment 3 and this segment does not have a significantly higher ratio of respondents from Northern Europe as in Segment 2.

### 5.5. Unobserved heterogeneity

Three of the studies reviewed estimate the demand for visual disamenity reductions using a random parameter logit (RPL) model [62]. Besides estimating a parameter for the mean preferences in the sample, the RPL model also allows for the specification of the distribution of relevant variables and subsequently the estimation of the standard deviation of the assumed distribution. Stated differently, given the choice of distribution, the model can be used to estimate how widely the preferences are distributed through the estimation of a standard deviation [30,62]. In Table 1 above, we present the means and standard deviations presented in the respective papers, as well as the thereupon estimated unconditional probability that the respondents hold negative or neutral preferences for reducing the visual disamenities (see for example Kataria [25] and Susaeta et al. [53] for a similar approach). The estimated probabilities are an approximation and so are conditional on the estimated means and standard deviations being correct.

First, all papers assume that the unobserved heterogeneity in preferences for visual disamenity reductions is normally distributed[6]. Based on this assumption, the estimated standard deviations are relatively large compared to the estimated means. This suggests that some proportion of the samples have no demand for visual disamenity reductions or might even have a positive demand for being able to see offshore wind farms from the coast. This is confirmed in the rightmost column, in which we have estimated the sample probability of having non-positive demand for visual disamenity reductions. Assuming that the estimated means and standard deviation are the true sample parameters, the estimated probabilities range from nearly zero to as high as approximately 50%. This suggests that even though the samples, on average, express a positive demand for reducing the visual disamenities from offshore wind farms, the possibility of having a significant proportion of the population that enjoy having offshore wind farms in the viewshed should not be disregarded. In the same line, referring to the recreational demand study in Landry et al. [41] these results indicate that an offshore wind farm might even be a positive attribute in the choice of beach to visit

[6] Ladenburg et al. [36] and Krueger et al. [40] state that other distributions have been tested, but that these do not change the conclusion of their papers in terms of the demand estimated at the mean. Naturally, assuming a lognormal or uniform distribution will have an influence on the distribution of utility of reducing the visual disamenities.

## 6. Conclusion and recommendations

The present review focuses on studies eliciting the demand for visual disamenity reductions from offshore wind farms. The relevance of these studies is supported by the expected annual wind power development level of more than 35 GW worldwide [63]. Unless the planned wind farms are located at relatively large distances from the coast, the offshore wind farms are anticipated to significantly change the viewshed of the coastal areas affected. This review points out that the change in the viewshed might be for the worse, as the respondents generally hold significant preferences for reducing the visual disamenities from offshore wind farms. That being said, the studies in the review also reveal

that seeing an offshore wind farm from the coast is not an equally negative issue for all parts of the sampled populations. Accordingly, substantial variation in the preferences exists. Preferences for reducing the visual disamenities are found to be stronger among beach users, people living close to the area chosen for development, people with higher levels of income and education, as well as older people. In addition, several of the reviewed papers report that a considerable share of the respondents do not hold significant preferences for reducing the visual impacts from offshore wind farms at all. However, the review also emphasizes that the spatial- and experienced-based drivers in demand are scarcely described in the literature and call for further investigation. Finally, the results from the surveys indicate a diminishing marginal demand for disamenity reductions. The demand for moving an offshore wind farm an addition km further away from the coast is higher for wind farms at near shore location when compared to locations further offshore. This suggests that unless the marginal costs of moving wind turbines to large distances from the coast are small, near or medium range distances seems to be the optimal location from a visual disamenity point of view.

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